

Comparative Optical Radiation Safety Analysis of New LED - Devices and -Lamps

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Abstract

The inclusion of LEDs (and with it optoelectronic devices in general) in the scope of the international laser safety standard IEC 60825-1 was a main force for fundamental alterations and transformations of the requirements and classification structure. The actual outcome, for this, historical for coherent and monochromatic sources developed standard, is the very recent issued "Amendment 2".

With roughly the same background, simultaneously also the generally international accepted recommendations for hazard assessments of incoherent sources (such as those from CIE or ANSI/IESNA) were improved, adapted and LED sources were verbatim included.

Both sets of requirements are now in parallel (with sometimes different results and implications) and LED-users and —manufacturers are unsure what's to be followed and how to proceed.

The present contribution summarizes the peculiarities and limitations of LEDs, compared with lasers and conventional incoherent sources, determines the impacts of "Amendment 2" and of the actual CIE-report on LEDs as well and compares the results.

LEDs: the "interlink" between coherent and incoherent optical sources

When hearing the term "LED" most people are thinking of small coloured indicator lamps on their PC-monitor, battery charger, etc. The dynamic development in the semiconductor technology now allows to produce different optoelectronic sources, also collectively called LED, but which are more or less close to laser devices. According to the growing variety of applications, modern optoelectronic semiconductor devices range from coherent single mode, multi-mode laser diodes, superluminescent diodes, high radiance diodes up to really incoherent "surface emitting" LEDs and recently even broadband LEDs with luminescence conversion (e.g. "white") — quasi on a sliding scale, depending on the design and sometimes even on the mode of operation. A distinction between what we usual call Laser and LED (stimulated or spontaneous emission) is simple not applicable.

The permanent increased efficiency with this developments raise the question of optical radiation safety. Therefore, LEDs were included into the requirements and safety regulations for lasers as well as for conventional lamps. Whereas the LED-inclusion into the IEC-laser safety regulations was initiated by the similarity of some LED types and applications with lasers, the inclusion of LEDs into optical safety regulations for incoherent broadband optical sources (such as those from CIE) was caused by the similarity of some (other) LEDs with lamps.

However, the optical radiation (and the possible hazard) from LEDs does differ in various aspects from laser sources and conventional lamps as well; generally they lie between incoherent broadband sources and coherent laser sources:

- the spectral radiation bandwidth of some ten nanometers is neither monochromatic nor broadband
- the spatial distribution of the emitted radiation ranges from cosine characteristics up to a nearly concentrated beam with any variation in between
- the source size is in most cases not only determined by the chip size but also by the package, and it mainly acts as an intermediate source between point (collimated laser beam) and extended source (most lamps).

Two different optical radiation safety approaches

Although they were developed from almost the same experimental basis, two different basic compilations of optical radiation threshold limit values (TLV) are existing (from ICNIRP), distinguishing between laser and incoherent optical sources i.e. related with the spectral bandwidth. Including optoelectronic devices now reveals the disadvantage of this "historically grown" distinction. Unfortunately both TLV-sets are not only pure biophysical data but already at that stage connected with different safety considerations. The TLV for (mostly "extended") incoherent sources are given in radiance, established on a pupil diameter of 3 mm, which has to be spectrally weighted with different action functions. The limits for monochromatic laser radiation are given per wavelength in irradiance and have to be measured with 7 mm aperture. Even the simple definition of the minimum pupil diameter

assessment of a certain LED with both guidelines under the same conditions sometimes leads to different results.

However, an actual problem in both cases is, that the measurements are rather complex and even mostly not realisable due to a lack of mandatory and proved advice^{/1/}. The most useful way of checking the implications of the different approaches is, to transform the TLV and the applicable measurement conditions altogether into related radiant or luminous intensity limit values which may also easily be compared with the appropriate data sheet values.

For LEDs with dominating photochemical hazards (e.g. "blue" and "white") the agreement of the results between CIE and IEC is roughly acceptable. This is no real surprise, since this newly introduced laser limits were directly derived from the limits for incoherent sources. For LEDs in the thermal hazards range in contrast, the deviation between laser- and lamp- limits is remarkable.

Situation and suggested solution

Based on the exposure limit values for laser, the safety classification requirements by product emission limits of the IEC standard 60825-1 were developed - again with some worst case assumptions for exposure duration, viewing distance, optical instruments. When used on LEDs, the result is mostly an overestimation of the real risk. A similar standardised safety classification requirement for incoherent optical sources is not existing. Unfortunately, in Europe the laser safety standard is listed under the "low voltage directive": each LED product has demonstrable to comply "by law" — in contrast to a conventional sources in the same application. This problem has satisfactory and equitable to be solved on the long run.

Obviously, visible LEDs are generally less hazardous compared with (infrared) IREDs: like with other bright light sources the natural aversion responses - such as turning away, the blink reflex and pupil contraction - afford very effective protection. In a first approach one could therefore say: "visible" LEDs shall better be treated with the regulations for incoherent sources, but "invisible" should follow the classification requirements of the laser safety standard. This solution is partly inappropriate and at best temporary:

- "visible" LEDs not only being used for illumination or signalling purposes, but also, like IREDs, for data transmission e.g. with plastic optical fibers
- new sources for visible applications (e.g. VCSEL) are to be expected, which are (as stimulated emitters) definitely within the scope of the laser safety standard
- the inflexible worst case assessment conditions of the laser safety standard principally does not mach to the application of divergent (incoherent or coherent) sources. The "inverse square law" on one side require high radiant intensities but limit also strongly the achievable hazard distance

WG 11 of IEC TC 76 therefore currently tries to overcome this situation by subsidiary application related standards respectively technical reports: each possible device in a certain application area has to meet the same safety requirements, which are also application specific modified.

Attempts to solve the problem by sorting potentially "hazardous" from "harmless" devices by their terminations, like in a recent ICNIRP-issue "LED-statement"^{/2/}, might help temporary at best: due to the very dynamical development of the optoelectronic technology, this might be true today but even wrong tomorrow. Generally, new device types are to be expected. More appropriate and not time-dependent is the physical description of the sources by their hazard related data.

However, the optoelectronic devices in general reveal, that the "historical grown" distinction between optical radiation safety limits for lasers and lamps is obsolete. The best way to solve the situation seems to identify and to close of the existing discontinuities, puzzles and gaps between both fundamental limit sets as already initiated by IEC TC 76, WG 9, to free them from safety considerations in order to establish a single most homogeneous basis of pure biophysical data for optical hazard assessments ("on a sliding scale") in all cases, based on the specific source characteristics and the use conditions. On this basis, a safety classification requirement is necessary for sources only, where an individual cannot check the possible hazard and must be protected (e.g. collimated beams, infrared). This could be a challenging and valuable task for CIE.

/1/ Horak, Neuhaus ILSC'01, in preparation

/2/ Health Phys. Vol.78 (June 2000), No. 6, pp744-752